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(U 338-E)

December 14, 2012, Letter From Mitsubishi Heavy Industries to Edward Avella Regarding Repair Options

Before the
Public Utilities Commission of the State of California

Rosemead, California
May 14, 2013

Confidential -

MNES
SONGS Project Office
14300 Mesa Road (G55-SGR1)
San Clemente, CA 92672

December 14, 2012 MKT-NSL-120060

Mr. Edward Avella
Director – Steam Generator Repair Project
Southern California Edison
14300 Mesa Road (G55-SGR1)
San Clemente, CA 92672

Subject: Repair and Replacement Options

Reference: SGR-L-M-MHI-111312124234

Dear Mr. Avella:

We are writing to discuss the options to address the tube wear in the steam generators at SONGS Units 2 & 3 discussed by Southern California Edison ("SCE") and Mitsubishi Nuclear Energy Systems, Inc. ("MNES") and Mitsubishi Industries, Ltd. ("MHI" and together with MNES, "Mitsubishi"). This letter provides Mitsubishi's summary assessment of these options.

Since the detection of tube wear at SONGS Units 2 & 3, Mitsubishi has worked with SCE to investigate their causes. This investigation has been difficult and time consuming because the tube-to-tube wear ("TTW") is a first-of-a-kind phenomenon and never before experienced in an operating steam generator. Evaluation of such first-of-a-kind phenomena is understandably more time consuming and involves more effort than does resolution of a known issue. Determination of acceptable countermeasures is also more time consuming.

As a result of our investigation, Mitsubishi has determined that the cause of this unexpected phenomenon is the combination of insufficient tube-to-AVB contact force and high localized thermal hydraulic conditions.

In parallel with the mechanistic cause investigation, Mitsubishi has also been diligently considering numerous repair options to address the tube wear observed at SONGS Units 2 & 3. We have considered various approaches to improve both tube support conditions and thermal hydraulic conditions to prevent continuation of the tube wear.

Mitsubishi has evaluated several AVB repair options to improve the tube support conditions in the SONGS Unit 2 and Unit 3 steam generators and has performed mock-up tests to examine the practicality of installation and effectiveness of these repair options. The NRC and SCE witnessed the testing in October of 2012. Based on the results of technical analyses of critical factors and these mock-up tests, Mitsubishi has determined that the insertion of "thicker AVBs" is a practical and viable repair option. (Please see Attachment-1)

The "thicker AVB" repair option provides for the insertion of thicker AVBs at the 45° and 135° locations in the even-numbered tube columns, between columns 66 and 112. This option introduces tube to AVB contact forces in excess of 30N throughout this region which will prevent tube in-plane displacement and tube-to-tube contact. The thicker bars will also increase the effectiveness of other tube support locations throughout the U-bend. The stability ratios for fluid elastic instability are significantly smaller and tube wear due to random vibration is greatly reduced.

In addition, improvements in the thermal hydraulic conditions of the steam generators can be made to accompany the thicker AVB repair. By changing the operating parameters within ranges provided by SCE, the thermal hydraulic conditions associated with 100% power operation can be reduced to a level below that of the Unit-3 tubes that exhibited TTW (i.e. reducing the maximum steam quality from 0.899 to 0.803 and the maximum void fraction from 0.996 to 0.989). This is accomplished by changing secondary water level, feed water temperature and RCS temperature. Such changes lower the thermal hydraulic conditions below the threshold associated with the observed TTW phenomenon (i.e. maximum void fraction >0.993).

Mitsubishi currently estimates that completion of the detail design, tooling and field implementation of the thick AVB repair will require one year, not taking into account possible additional time that might be required for NRC review.

Mitsubishi has also commenced a parametric study for the conceptual design of a new SG configuration to achieve the maximum practical improvement in the U-bend thermal hydraulic conditions associated with SONGS 100% power operation. This study includes replacement of the SG tube bundle (lower assembly) or, alternatively, the replacement of the entire steam generator. Design variables being considered include tube size, tube spacing, number of tubes, and the SG operating conditions. Preliminary analyses indicate that the thermal hydraulic conditions can be reduced to a level equivalent to that of currently operating steam generators. At the same time, modifications can be made to the AVB design to provide additional in-plane support to avoid in-plane fluid elastic instability and to minimize tube wear due to random vibration. Mitsubishi currently estimates that the schedule for both of these options (i.e., the design, manufacture and delivery of either replacement tube bundles or entire new replacement steam generators) would take five and a half years. Mitsubishi's preliminary schedule is enclosed as Attachment-2.

Accordingly, Mitsubishi concludes that both the "thicker AVB" repair and replacement of the entire tube bundle/entire SG are technically viable. Replacement of the entire tube bundle/SG provides the ability to make the most extensive design changes. There are obviously other considerations that must be taken into account. Mitsubishi will continue to work with SCE to develop a mutually agreeable and appropriate method to address the tube wear in the steam generators at SONGS Unit 2 & 3 in accordance with the Purchase Order. In this regard, enclosed as Attachment-3 are Mitsubishi's responses to SCE's internal criteria attached to your letter of November 13 (SGR-L-M-MHI-11312124234) for evaluating repair or replacement of the steam generators.

Sincerely yours,

H Kaguchi.

Hitoshi Kaguchi, Ph.D, P.E.
Project Director, SONGS Project
Mitsubishi Nuclear Energy Systems, Inc.

Evaluation of Repair Methods

Non-proprietary version

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Contents

Abstract

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- This document provides the evaluation results of Thicker AVB's effectiveness as a repair method

- It is confirmed that Thicker AVB can prevent in-plane FEI and mitigate random vibration wear

- Feasibility of Thicker AVB insertion is studied by using tube bundle mock-up

1. MHI's Selection of Repair Method

1.1 Type of Tube Wear & Causes

1.2 Repair or Replacement Method as Candidate of Recovery Action

1.3 Selection of Repair Method

1.4 Validation Flow Chart of Selected Repair Method

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1.1 Types of Tube Wear & Causes

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- RSGs for SONGS Unit 2 and 3 experienced tube wear due to flow induced vibration.

Type of wear	Number of tube with wear & plugged tube				
		2A	2B	3A	3B
Tube to tube wear (Type-1)	Wear	2	0	165	161
	Plugged	2 [+212]*1	0 [+109]*1	165 [+128]*1	161 [+164]*1
AVB wear (Type-2)	Wear	802	595	714	737
	Plugged	0	4	0	1
Tube Support Plate wear (Type-3)	Wear	53	137	15	20
	Plugged	0	0	0	0
Retainer bar wear (Type-4)	Wear	4	2	1	3
	Plugged	4 [+90]*1	2 [+92]*1	1 [+93]*1	3 [+91]*1
Total plugged tube		308	207	387	420

Note : Tubes with multiple wear will only be counted once according to the following sequence from the highest priority; Type-1, Type-2, Type-3, and Type-4 (for example, a tube with Type 1 and Type 2 wear will be counted as a tube with Type-1 wear only).

***1:Number of tubes preventively plugged**

1.1 Type of Tube Wear & Causes

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- **Causes of each type of wear**

Type of wear	Causes
Tube to tube wear (Type-1)	In-plane FEI vibration of tube due to ➢ Localized high thermal-hydraulic conditions ➢ Insufficient contact forces
AVB wear (Type-2)	Random vibration of tube due to ➢ Localized high thermal-hydraulic conditions ➢ Insufficient contact forces
Tube support plate (TSP) wear (Type-3)	Random vibration of tube
Retainer bar wear (Type-4)	Random vibration of retainer bars due to lower natural frequency

1.2 Repair or Replacement Method as Candidate of Recovery Action

- Recovery action should satisfy the following:
  - Prevent in-plane FEI under operating condition of 100% power output
  - Limit tube wear rate so that tube plugging will not exceed 8 % under operating condition of 100% power output for 40 year design life

1.2 Repair or Replacement Method as Candidate for Recovery Action

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- The four options below have been identified as potential SG recovery actions
- The design and evaluation of Options 3 & 4 (replacement) are on-going. A detailed evaluation is beyond the scope of this document.
- This document presents information for evaluating the adequacy of Options 1 and 2.

Option	Description
Option 1	Addition of Thicker AVB (Repair Method Case 1(*)) + Changing operating conditions
Option 2	Addition of Thicker AVB & 30 degree AVB (Repair Method Case 2(*)) + Changing operating conditions
	Addition of Comb AVB (Repair Method Case 3(*)) + Changing operating conditions
Option 3	Bundle Replacement -Lower portion replacement -Lower portion replacement +Improvement of upper portion
Option 4	Entire Steam Generator Replacement

(*)Refer to MHI presentation Material "Verification of Repair Method for Tube Vibration Issue" dated Nov.16, 2012

1.2 Repair or Replacement Method as Candidate of Recovery Action

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- For the repair methods (Options 1 & 2), countermeasures for each type of wear are summarized below

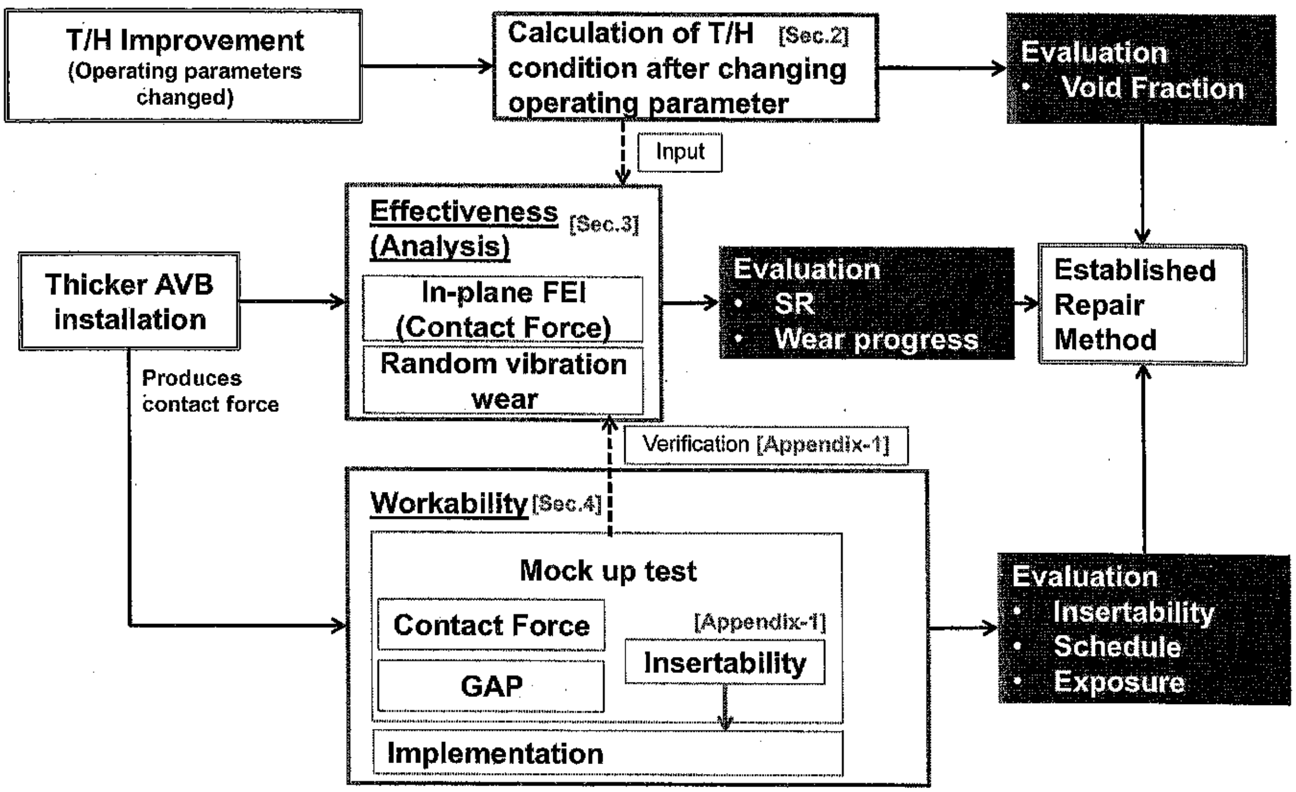
Type of wear	Countermeasures
Tube to tube wear (Type-1) AVB wear (Type-2)	➢ Reduce void fraction in the U-bend region →Change operating parameters to improve T/H ➢ Produce sufficient contact force or provide a physical restraint between Tube and AVB →Additional AVB installation ➢ Plug tubes as necessary
Tube Support Plate wear (Type-3)	➢ None ✓ Manageable by monitoring wear progress at regular outage
Retainer bar wear (Type-4)	➢ Keep plugs on all tubes that have possibility of contact with retainer bar

1.3 Selection of Repair Method

- MHI has selected Option 1 (Repair method Case 1). The selection process was explained in detail in MHI's presentation "Verification of Repair Method for Tube Vibration Issue" dated Nov.16, 2012

Repair Method	Evaluation			
	Insertability	Workability	Effect	Applicability
Option 1 [Case 1] Thicker AVB (2 sides)	Easy insertion	Exposure is estimated as [ ] man·rem. No problem of insertion in water	Contact force by Thicker AVB is enough for the prevention of TTW	Applicable
Option 2 [Case 2] 30 deg. AVB + Thicker AVB (center)	The insertion is possible, but actual work is time consuming	The insertion is difficult and exposure is very high ([ ] man-rem)	- (Effective for the prevention of TTW)	Challenging
Option 2 [Case 3] Comb AVB	The insertion is impossible.	-	- (Effective for the prevention of TTW)	Not applicable

1.4 Validation Flow Chart of Selected Repair Method



2. Improvement of Thermal Hydraulic Condition in the U-bend of the bundle

2.1 Purpose of T/H Improvement
2.2 Targeted T/H Condition
2.3 Candidates for T/H Improvement
2.4 Summary

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2.1 Purpose of T/H Improvement

- Tubes in the high void fraction (Max.[ ]) or high steam quality (Max. [ ]) region of the tube bundle are more susceptible to in-plane FEI and random vibration
- Reduction of void fraction and steam quality contributes to prevention of in-plane FEI and mitigation of random vibration.
- This section describes the effectiveness of operating parameter changes resulting in improvement of T/H condition

2.2 Targeted Thermal Hydraulic Condition

- Upper limits for void fraction/steam quality conditions are set based on observed SG wear

Item	Target condition	Reason
Max. Void fraction	[ ]	There is correlation between TTW occurrence and max void fraction. Tubes with TTW were observed in the region where max void fraction was greater than[ ].
Max. Quality	[ ]	There is correlation between TTW occurrence and max quality. Tubes with TTW were observed in the region where max quality was greater than[ ].

2.2 Target Thermal Hydraulic Condition

2.3 Candidates for T/H Improvement

- Selection of Candidates for T/H improvement
  - Effective parameters for reduction of void fraction and steam quality
    - Circulation ratio (CR) increase
    - Steam pressure increase
  - In order to improve the T/H condition, the following three candidates (changes in operating parameters) were selected:

Element of improvement	Improvement Candidate	Parameter change	
Circulation Ratio Increase	Increased secondary water level (%)	[ ]	Distance between water level and middle deck plate must be kept at approx. [ ] mm (water level [ ]%) to guarantee the separator performance.
	Reduced FW temperature (°F)	[ ]	In the temperature range provided by SCE
Secondary Pressure Increase	Increased T COLD (°F)	[ ]	In the temperature range provided by SCE

2.3 Candidates for T/H Improvement

- The effect of combination of the three methods
  - Max. steam quality [ ] and Max. void fraction [ ] can be achieved

Main Parameter	Unit	Original	Improvement
Thermal Power	(%)	[ ]	
Number of plugged tube (Simulate 3B-SG)	(-)	[ ]	
RCS flow rate	(gpm)	[ ]	
Water Level	(%)	[ ] →	[ ]
T cold	(°F)	[ ] →	[ ]
Feedwater temperature	(°F)	[ ] →	[ ]
Steam pressure	(psia)	[ ]	[ ]
Circulation Ratio	(-)	[ ]	[ ]
Max. steam quality	**(-)**	[ ] ⇒	[ ]
Max. void fraction	**(-)**	[ ] ⇒	[ ]

2.3 Candidates for T/H Improvement

- Void fraction and steam quality distribution
  - Regions of high void fraction and steam quality are decreased

2.3 Candidates for T/H Improvement

- Stability Ratio for In-Plane FEI
  - Application of three methods reduces the SR value of tubes
  - On the other hand, half of the tubes still have a SR value of more than 0.75

2.4 Summary

- The following methods of changing the operating parameters are selected for T/H condition improvement (void fraction reduction).
  - Increased secondary water level
  - Reduced FW temperature
  - Increased T COLD
- The void fraction and steam quality are reduced to a range where there are no tubes with TTW by applying the selected three methods.
- SR value of tubes are improved, but half of tubes still have the SR value of more than 0.75 assuming all support points are inactive

3. Evaluation of Effectiveness of Thicker AVB

3.1 Introduction
3.2 Items to Confirm Thicker AVB Effectiveness
3.3 Evaluation Method
3.4 Evaluation of Effectiveness
3.5 Side Effect
3.6 Summary

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3.1 Introduction
<Concept of Thicker AVB insertion region>

Thicker AVB insertion region

- Thicker AVBs are installed to the center region of tube bundle in where most wear occurred (See the highlighted regions above)
- All tubes with random vibration wear outside of the highlighted region are plugged and then the Thicker AVB insertion is not necessary there because TTW will not occur on tubes which do not have wear during the previous operating cycle even if SR value is greater than 0.75

3.1 Introduction
<Expected Effect of Thicker AVB Insertion>

(1) Effect of Thicker AVB insertion on SR improvement and Random Vibration

- Thicker AVBs are installed at two locations in order to generate support points
  - Improvement of SR for in plane FEI
  - Reduction in progress rate of tube random vibration wear
    (Eigenvalue of tube is increased and random vibration amplitude is reduced)

3.1 Introduction
-- Expected Effect of Thicker AVB Insertion

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(1) Effect of Thicker AVB insertion on SR improvement

- Thicker AVB insertion enables the tubes in the Thicker AVB insertion region to satisfy the criteria for in-plane SR value of less than 0.75 if the insertion points are active

3.2 Items to Confirm Thicker AVB Effectiveness

- <u>In Plane FEI</u>
  In plane FEI should not occur
  - ➢ Contact force generated by thicker AVB between tube and thicker AVB should be greater than Pinning force ([ ] N) at each insertion point.
- <u>Random Vibration</u>
  Plugging rate should not exceed 8% during 40 year design life
  - ➢ The number of tubes with over 35% wear depth should be less than 8% considering work rate reduction due to Thicker AVBs.
  - ➢ The impact of a potential work rate increase due to random vibration of existing AVBs next to a Thicker AVB should be evaluated.

3.3 Evaluation Method

3.4.1 Evaluation of Effectiveness -- in-plane FEI

(1)-1 Pinning Force (Selected Tubes for Evaluation)

- For the 2 Thicker AVBs, the contact forces required in order to prevent slipping between Tube and Thicker AVB (as pin support) are evaluated. (IVHET Analysis)
- Tubes on which highest contact force are required are the tubes with highest SR
- The required contact force for these tubes is set as the criteria for all tubes for conservatism
- Plugged and non-plugged tubes with highest in-plane SR are evaluated

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(1)-2 Pinning Force (Analysis Method / Model)

3.4.1 Evaluation of Effectiveness -- In-plane FEI

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(1)-3 Pinning Force (Analysis Result)

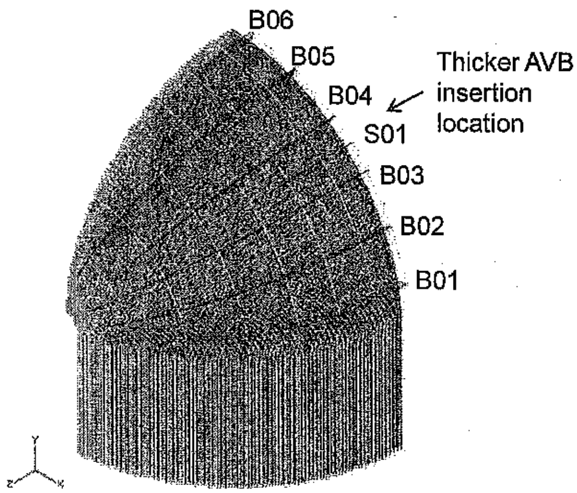
- Maximum Pinning Force obtained is[ ]N
- Required Contact Force of Additional Thicker AVB is set as[ ]N
  (2 Thicker AVB Insertion locations are considered as pin supported under the condition of[ ]N Contact Force)

		Non-plugged Tubes	Plugged Tubes (with J-Stabilizer)
Tube Address		Row[ ] Col[ ]	Row[ ]Col[ ]
Maximum Pinning Force (*) [N]	HOT	[ ]N	[ ]N
	COLD	[ ]N	[ ]N

(*) 2 σ of the reaction forces of in-plane and out-of-plane (Same evaluation as OA for Unit-2)

(2)-1 Contact Force by Thicker AVB Insertion (Analysis Method / Model) (1/2)

- Contact Force Analysis Model: Full Bundle Model (ABAQUS)
  - Tube bundle are modeled based on the Unit-3 model used for the Unit-2 OA (Unit-3 tube wear situation is simulated as gap between tube and AVB)
  - Variability in manufacturing tolerance, tube diameter, tube flatness, AVB thickness, AVB twist and TSP hole pitch, is taken into consideration in this model
  - Tube-AVB gap and material properties during operating Hot condition are modeled.



Analysis Model after Thicker AVB Insertion

3.4.1 Evaluation of Effectiveness -- In-plane FEI

(2)-1 Contact Force by Thicker AVB Insertion (Analysis Method / Model) (2/2)

- Modeling of Thicker AVB
  - The thickness of the Thicker AVB is selected to obtain contact forces higher than the pinning force with considering the manufacturing dispersion and 40 years wear progress
  - The gap element has a negative input value for the Thicker AVB insertion as compression force
  - Contact force can be controlled by changing the AVB thickness

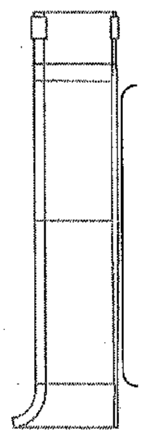
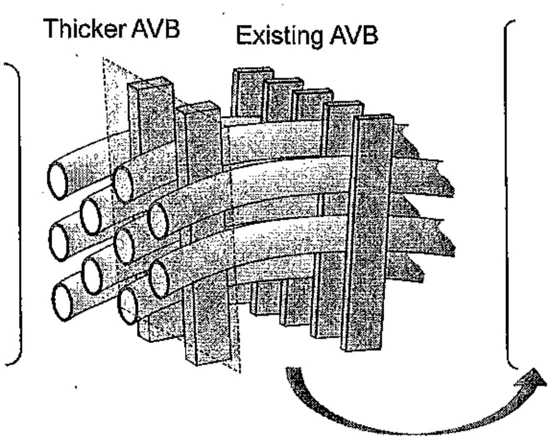


Image Thicker AVB



3.4.1 Evaluation of Effectiveness -- In-plane FEI

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(2)-3 Contact Force by Thicker AVB Insertion (Analysis Result / After Repair)

- Even if manufacturing dispersion is considered, it is confirmed that the Contact Forces at Thicker AVB-tube contact points exceed the Pinning Force of[ ]N
- For tubes within the Insertion Range with 2 support points, FEI will not occur as SR<0.75

[ ]

Contact Force at thicker AVB inserted location (N)

3.4.1 Evaluation of Effectiveness -- In-plane FEI

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(2)-4 Contact Force by Thicker AVB Insertion (Analysis Result / at 40 years)

- Contact Forces at Thicker AVB-tube contact points exceed the Pinning Force of [ ]N even if wear progress at existing AVB locations at 40 years is considered
  - Wear volume at 40 years is evaluated in Sec.3.4.2
- Adequate thickness of Thicker AVB will be designed at detail design stage by considering the tube wear distribution and progress

[ ]

Contact Force at thicker AVB inserted location (N)

3.4.2 Evaluation of Effectiveness
-- Random Vibration Wear (Tube)

(1) Evaluation Method

- Acceptable maximum number of the tubes for 8% plugged at 40 years of operation
  - Total tubes in SG: [ ]tubes x 8% plugging =[ ]tubes
- Tubes which exceed 35% wall thickness are plugged
- Wear progress rate is conservatively evaluated as constant, because actual tube's random wear progress is saturated
- Considering Work Rate improvement by Thicker AVB insertion based on IVHET analysis result

[ ]

3.4.2 Evaluation of Effectiveness -- Random Vibration Wear(Tube)

(1) Evaluation Method (2/2)

- Wear Rate (WR) is conservatively evaluated for tubes with highest SR
  - Non-plugged Tube: Row[ ] Col[ ]
  - Plugged Tube: Row[ ]Col[ ]
- Wear progress after Thicker AVB insertion is evaluated by using the ratio of WR after to WR before Thicker AVB insertion.
  - WR ratio = ($WR_{\text{after thicker AVB insertion}}$)/($WR_{\text{before thicker AVB insertion}}$)
- WR is calculated by IVHET under the AVB support and gap conditions on the next two slides
- WR is conservatively assumed to be constant during 40 years design life

3.4.2 Evaluation of Effectiveness
-- Random Vibration Wear (Tube)

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(2) Evaluation Condition (AVB Support Condition)

Evaluated Tube	Thicker AVB	Existing AVB Condition
R[ ]C[ ]	after insertion	[ ] inactive
	before insertion	[ ] inactive
R[ ]C[ ]	after insertion	[ ] inactive
	before insertion	[ ] inactive

[ ]

- After Thicker AVB insertion
  - <u>Thicker AVB: Pin Support</u>
    Exceeds Pinning Force. No movement due to pinning and therefore no wear
  - <u>Existing AVB: [ ] points assumed inactive</u>
    [ ] existing AVB points are conservatively regarded as inactive.
    (WR after insertion is high ⇒ WR Ratio between after and before insertion become high)

- Before thicker AVB insertion
  - <u>Existing AVB: [ ] points assumed inactive</u>
    Random vibration analysis result with [ ] inactive points corresponds with the actual wear depth

3.4.2 Evaluation of Effectiveness
-- Random Vibration Wear (Tube)

(2) Evaluation Condition (Analysis Model / Work Rate)

3.4.2 Evaluation of Effectiveness -- Random Vibration Wear(Tube)

(3) Evaluation Result (1/2)

- The figure below shows the tube wear and plugging distribution at 40 years
- The total plugged tube number for each Unit is[ ](A-SG) and[ ](B-SG), respectively and plugging rate is less than 8%

Tube Plugging and wear distribution at 40 years (A-SG)

3.4.2 Evaluation of Effectiveness -- Random Vibration Wear(Tube)

(3) Evaluation Result (2/2)

Tube Plugging and wear distribution at 40 years (B-SG)

3.5 Side Effect -- Gap influence

- **Are gaps generated at lower rows than the Thicker AVB insertion rows?**

➡ The full bundle analysis result confirms that gaps at lower rows from Thicker AVB insertion area are almost same as before Thicker AVB insertion.

- **Does the insertion of the Thicker AVB increase the random vibration of adjacent AVBs?**

➡ The IVHET vibration analysis result confirms that random vibration of adjacent AVBs has no impact on tube WR.
See next slide.

- **Random vibration of Existing AVB (B03/B04) next to Thicker AVB**

The maximum Work Rate is not changed even considering tube's Work Rate due to existing AVB's vibration

3.6 Summary

(1) In-Plane FEI

- Criteria for plant operation at full power

In plane FEI should not occur

- Evaluation Result

By adjusting the thickness of Thicker AVB, contact forces generated at all thicker AVB insertion points can be greater than the pinning force ([ ]N) even if there is variability in manufacturing tolerance and wear progress at existing AVB locations

(2) Random Vibration

- Criteria for plant operation at full power

Plugging rate should not exceed 8% at 40 years

- Evaluation Result

It is confirmed that plugging rate does not exceed 8% based on tube vibration analysis result.

Repair by Thicker AVB satisfies with the repair requirement shown in Section 1

4. Implementation of Thicker AVB Installation

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4. Implementation of Thicker AVB Installation

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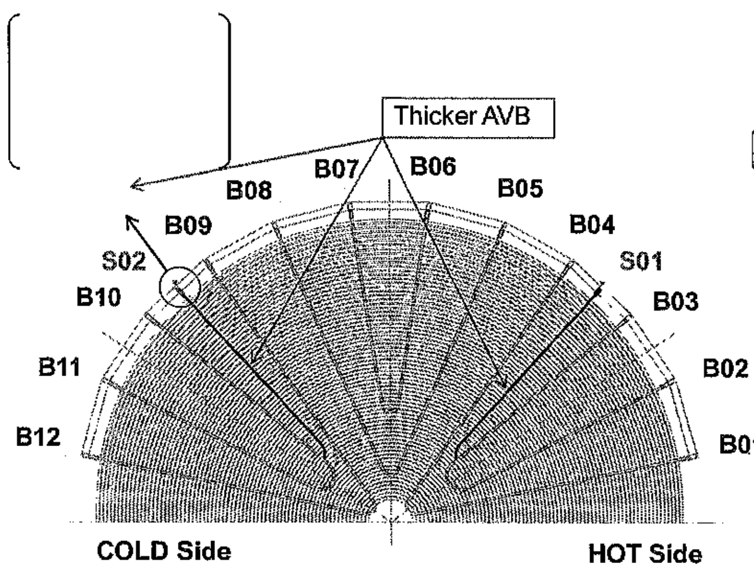
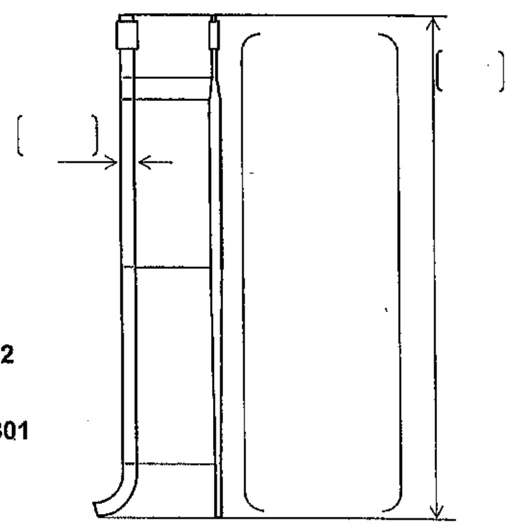
- MHI studied thicker AVB design and implementation procedure.
- MHI confirmed the feasibility of thicker AVB implementation.
  - There is little temporary alternation of SG for an accessability improvement.
    - Cut a part of separators
  - Dose exposure of worker was evaluated very low.
  - This method can be completed within a reasonable period except for authorization
  - Foreign material exclusion can be achieved by the conventional protection tool.

4.1 Design of Thicker AVB

- Thicker AVB insertion 2 Sides points.
- Thickness of Thicker AVB is [ ] ~ [ ]. (Adequate thickness will be designed at detail design stage)
- Thicker AVB insertion depth is Row [ ].
- Thicker AVB material will be the [ ].



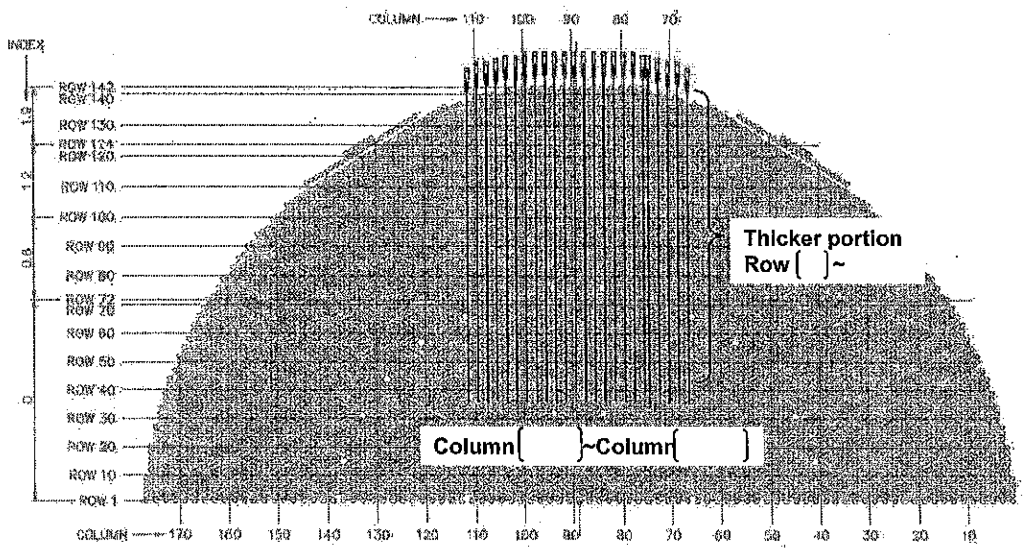
Thicker AVB insertion points



Thicker AVB Shape

4.1 Design of Thicker AVB

- Thicker AVB insertion region is Column [   ]to Column [   ].
- Thicker AVB insertion [   ]lanes at 2 Sides points.



Thicker AVB insertion region

4.2 Planning of Implementation- Step 1

4.2 Planning of Implementation- Step 2

4.2 Planning of Implementation- Step 2

4.2 Planning of Implementation- Step 3

4.2 Planning of Implementation- Step 4

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4.2 Planning of Implementation- Step 5

4.2 Planning of Implementation- Step 6

4.2 Planning of Implementation- Step 7

4.2 Planning of Implementation- Step 8

4.2 Planning of Implementation- Step 9

4.2 Planning of Implementation- Step 10

4.2 Planning of Implementation- Step 11

4.2 Planning of Implementation- Step 12

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4.2 Planning of Implementation- Step 13

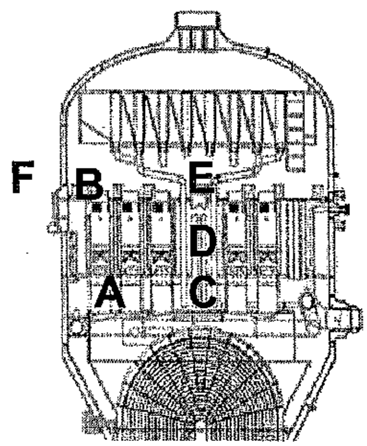
4.2 Planning of Implementation- Step 14

4.3 Estimation of Radiation Exposure

- Estimated dose rate
  - Primary water :[ ]
  - Secondary water level:[ ]

[ ]

	Location	Rem/hr
A	Side of bottom deck plate	[ ]
B	Manway inside	[ ]
C	Center of bottom deck plate	[ ]
D	Center between middle deck plate and bottom deck plate	[ ]
E	Center of middle deck plate	[ ]
F	Outside of SG	[ ]



4.3 Estimation of implementation schedule & Radiation Exposure

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Step	days	Rem/h	ManRem
1 - [ ]	[ ]	[ ]	[ ]
2 - [ ]	[ ]	[ ]	[ ]
3 - [ ]			
4 - [ ]			
5 - [ ]			
6 - [ ]			
7 - [ ]			

4.3 Estimation of implementation schedule & Radiation Exposure

Step	days	Rem/h	ManRem
8 - [ ]			
9 - [ ]			
10 - [ ]	[ ]	[ ]	[ ]
11 - [ ]			
12 - [ ]			
13 - [ ]	[ ]	[ ]	[ ]
14 - [ ]	[ ]	[ ]	[ ]
Total	[ ]	-	[ ]

4.4 AVB Repair Experience

- MHI has many experience of similar replacement work of AVB to domestic plants. This design concept is nearly same as thicker AVB to be tested at this time but it has different structure.
- The type of thick AVB: Expandable type (Slide AVB) ,0.4"t
- Tube design: 7/8" dia. & Square array

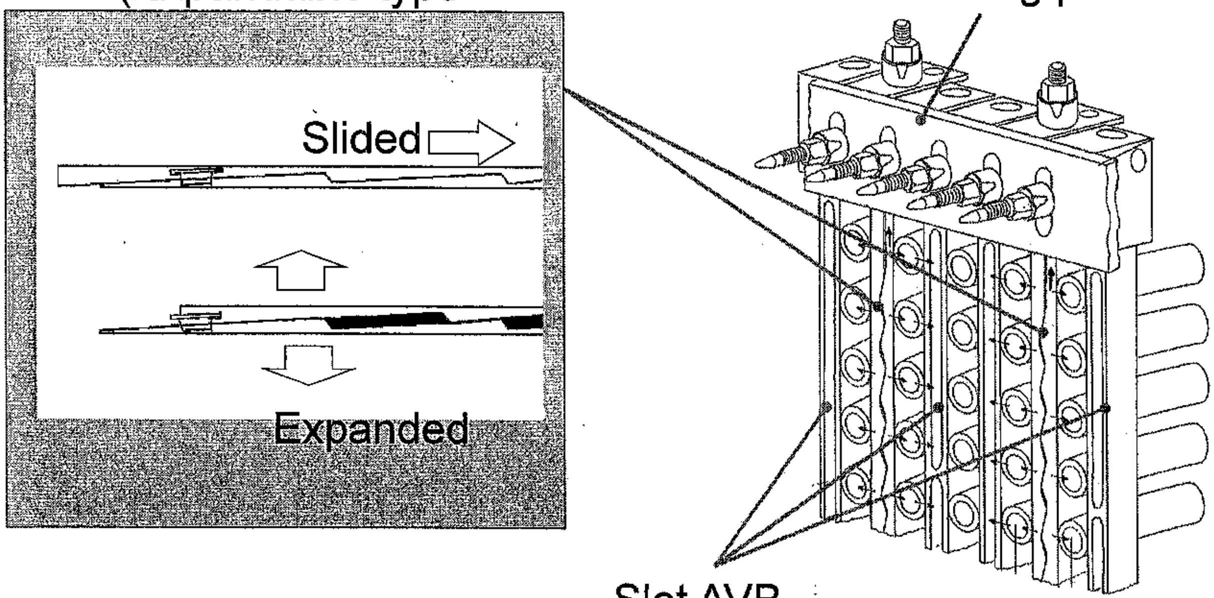
Table : AVB Repair Experience

Date	Plant	Number of SG
1990/03	Domestic "A"	3
1990/09	Domestic "B"	4
1991/03	Domestic "C"	3
1991/04	Domestic "D"	3
1991/07	Domestic "E"	3
1991/09	Domestic "F"	3
1992/01	Domestic "G"	2

Date	Plant	Number of SG
1992/05	Domestic "H"	2
1992/05	Domestic "I"	3
1992/05	Domestic "J"	2
1992/05	Domestic "K"	2
1992/09	Domestic "L"	2
1992/10	Domestic "M"	4

4.4 AVB Repair Experience – Structure of expandable AVB

Thicker AVB
(Expandable type



5. Remaining action items and Schedule

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5. Schedule for Implementation (draft)

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- In case of the application of thicker AVB method as short term repair, following actions are necessary.

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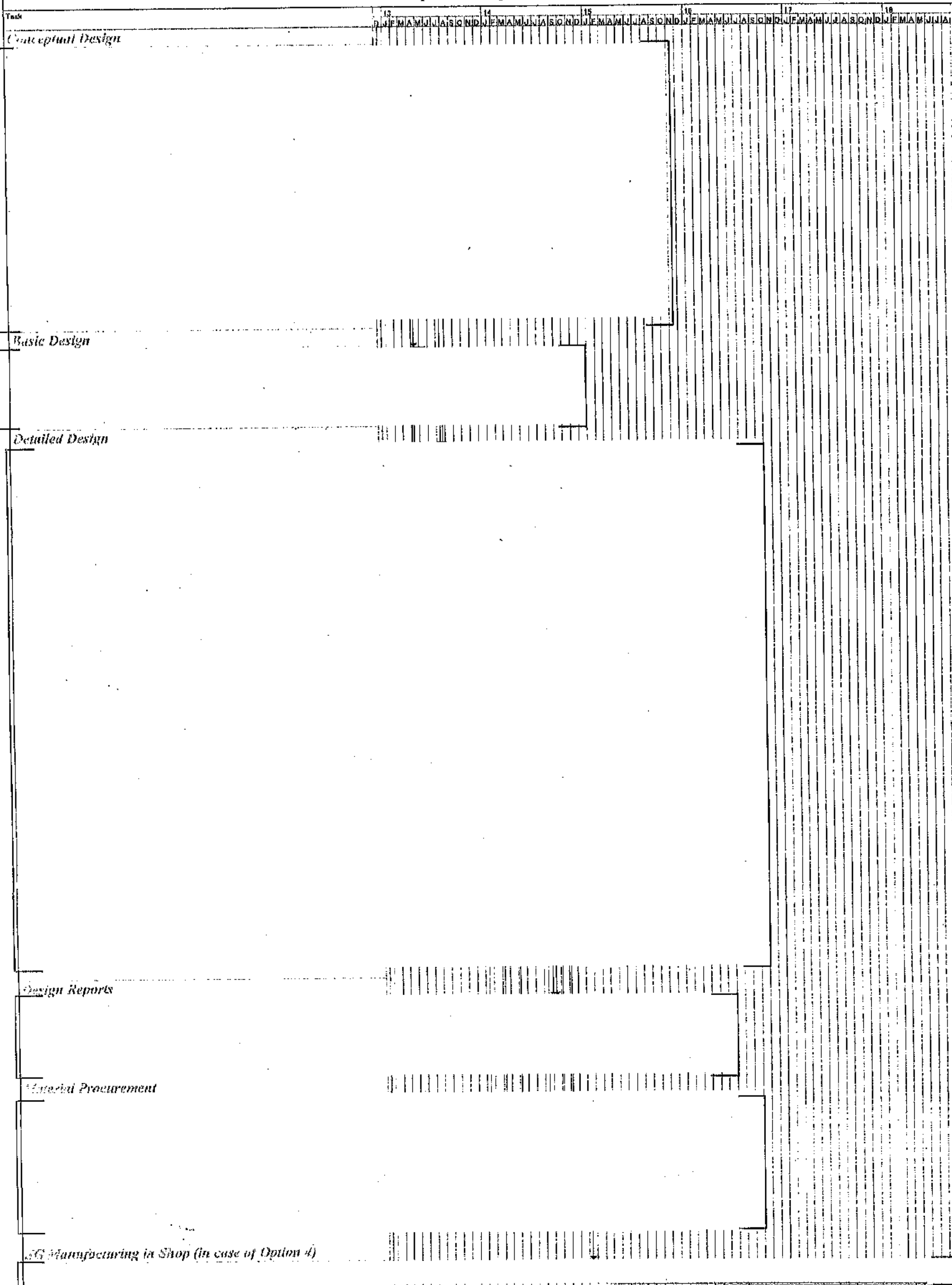
SONGS Option 3 / Option 4 Schedule

2012.12.14



The comments to this paper has been prepared for non-binding technical discussion purposes. The comments are based on the assumption that the parties would be able to agree on terms and conditions to proceed with a replacement option. Any agreement to proceed shall be subject to negotiation, execution and delivery of a mutually acceptable and definitive agreement including commercial terms and conditions.

本設計工程の前提条件

Prerequisite Conditions

Attachment 3

SCE Repair Replacement Evaluation Matrix

This table is in a format and contains metrics created by Southern California Edison (SCE). Mitsubishi Heavy Industries (MHI) does not think that this table provides a complete or necessarily accurate set of criteria for evaluating the repair or replace option. Nor does it agree that these metrics are consistent with the obligations owed to SCE under the Purchase Order. MHI understands that responses are needed to facilitate an anticipated internal SCE conversation and are provided solely for that purpose. The responses are summary in nature in order to be consistent with the SCE proposed format. MHI looks forward to completing repairs or replacements in a manner that is mutually agreed upon by SCE and MHI, consistent with the obligations of the Purchase Order.

The information contained in this table should be considered preliminary as the associated evaluations for several options are still ongoing. The details for Options 3 and 4 in particular will become more defined as the design process continues.

The four options in the table are as follows.

Option 1: Insertion of Thicker AVBs at the [ ]° and [ ]° locations in the even number tube columns between columns [ ] and [ ] combined with changes to operating parameters to improve thermal hydraulic conditions.

Option 2: (i) Option 1 plus insertion of 30° AVBs or (ii) insertion of combined AVB combined with changes to operating parameters to improve thermal hydraulic conditions .

Option 3: Replacement of tube bundle (lower assembly) with one of a different configuration. [***Note: To consider alternative description of Option 3: Repair providing for replacement of SG tube bundle (lower assembly) with one of a different configuration.***]

Option 4: Entire SG Replacement

A. **Effectiveness**	**Option 1**	**Option 2**	**Option 3**	**Option 4**
1. Does the option resolve thermal hydraulic conditions such that SONGS can operate at all power levels without undue tube vibration or unacceptable wear?	[ ]	[ ]	[ ]	[ ]
[ ]				
i. What is the impact on SG performance (pressure drop, flow velocities, etc.)?	[ ]		[ ]	[ ]
ii. Is the stability ratio less than 0.75?	[ ]		[ ]	[ ]
iii. Can undue tube vibration or unacceptable wear be prevented?	[ ]		[ ]	[ ]
2. Does the option restore the design to ensure a thermal capacity of each SG of at least 1729 MWt?	[ ]	[ ]	[ ]	[ ]
i. What sustained power levels are acceptable for the proposed modification	[ ]		[ ]	[ ]
3. Does the option restore the full life of the SG components to forty years?*	[ ]	[ ]	[ ]	[ ]
[ ]				
i. What is the expected operating life of the repaired SGs?	[ ]		[ ]	[ ]
ii. What is the basis for operating life?	[ ]		[ ]	[ ]
4. Does the option restore the tube plugging margin to less than 8% at end of life?*	[ ]	[ ]	[ ]	[ ]
[ ]				
i. How does the option evaluate the existing degraded condition of the tubing?	[ ]		[ ]	[ ]
ii. How does the option address the existing degraded condition of the AVBs, and how can that degradation be qualified?	[ ]		[ ]	[ ]
[ ]				
iii. If the existing AVBs are being adjusted in position so they would be on virgin tube material, how will MHI quantify the amount of damage to the AVB itself and its effect?	[ ]		[ ]	[ ]
iv. Does the option reduce the risk of loss of adequate out-of-plane and in-plane stability on all tubes?	[ ]		[ ]	[ ]
v. How does the option address the presence of primary or secondary water inside those tubes removed from service (leakage via tube plugs or tube defects, or those already leaking)?	[ ]		[ ]	[ ]
[ ]				

B. Validation	Option 1	Option 2	Option 3	Option 4
1. Have the option and corresponding analyses been carried out successfully elsewhere within the nuclear industry (i.e., "no" if it is a first of a kind)?	[ ]	[ ]	[ ]	[ ]
Question B.1: Although many repairs to AVBs have been concluded successfully within the nuclear industry including by MHI, the specific Option 1 repair proposed has not been previously carried out.				
i. How was the analysis model for flow elastic instability validated (i.e., through testing or comparison)?	[ ]		[ ]	[ ]
ii. What analysis or testing has been done to prove that the proposed option will eliminate tube in-plane instability and tube-to-tube wear?	[ ]		[ ]	[ ]
[ ]				
iii. Were the wear calculations validated?	[ ]		[ ]	[ ]
a. What level of design review was performed?	[ ]		[ ]	[ ]
[ ]				
b. What are the expected tube wear rate at the AVB and the AVB material wear rate?	[ ]		[ ]	[ ]
c. What is the impact of the option on existing tube-to-TSP and tube-to-AVB wear rates?	[ ]		[ ]	[ ]
d. If additional AVBs are being added, is there a negative impact on the existing AVB gaps and associated wear?	[ ]		[ ]	[ ]
e. How will the option be monitored in the future to assure continued functionality and integrity?	[ ]		[ ]	[ ]
[ ]				
iv. Was the option evaluated by full-scale or mock-up testing?	[ ]		[ ]	[ ]
[ ]				
v. Has an independent review of the option method and associated analyses and calculations been conducted?	[ ]		[ ]	[ ]
vi. Will any special instrumentation be required to confirm that the option is effective?	[ ]		[ ]	[ ]
2. Was the option validated to be physically implementable within the SGs?	[ ]	[ ]	[ ]	[ ]
[ ]				
3. For all options involving installation of new hardware, has the new hardware been evaluated itself for flow induced vibration, structural integrity, and position stability at SG design and operating conditions?	[ ]	[ ]	[ ]	[ ]
4. For new AVBs, does the option address the true variability of the pitch changes that occur though the bundle due to both design incrementation* and fabrication variances?	[ ]	[ ]	[ ]	[ ]
[ ]				
5. Can the option be implemented without additional non-destructive examinations (NDE) being required or considered as a part of the process for verification?	[ ]	[ ]	[ ]	[ ]

C. Implementation	Option 1	Option 2	Option 3	Option 4
1. Has the proposed option been installed successfully elsewhere within the nuclear industry (i.e., "no" if it is a first of a kind)?	[ ]	[ ]	[ ]	[ ]
[ ]				
i. Will special or new equipment, tooling, or techniques be required?	[ ]		[ ]	[ ]
ii. Will special actions or equipment be required to ensure worker safety?	[ ]		[ ]	[ ]
iii. Will special training requirements be needed to install the option?	[ ]		[ ]	[ ]
[ ]				
2. Can the option be done within the physical limitations of the SGs or SG walls?	[ ]	[ ]	[ ]	[ ]
i. Are there any special spatial limitations or requirements?	[ ]		[ ]	[ ]
ii. Will any alterations to the SGs or SG walls be needed?	[ ]		[ ]	[ ]
3. Was full-scale testing of the option conducted and deemed successful?	[ ]	[ ]	[ ]	[ ]
[ ]				
4. Can the option be implemented within an acceptable amount of time? (MHI to provide durations for design and manufacturing & delivery and implementation)*	([ ] months)	([ ] months)	([ ] months)	([ ] months)
[ ]				
5. Have contingency plans, tools, and techniques been developed for restoring the SGs to pre-option conditions (i.e., "back-out" criteria) should option become impossible to complete?	[ ]	[ ]	[ ]	[ ]
i. Are there any unrecoverable mishaps* that could possibly occur?	[ ]			
[ ]				
6. Is the option adjustable following installation?	[ ]	[ ]	[ ]	[ ]
7. Can the option be implemented without special habitability (temperature, etc.) measures for personnel (e.g., working inside SG)?	[ ]	[ ]	[ ]	[ ]
i. What is the dose or exposure estimate?	[ ] ManRem	[ ] ManRem	[ ]	[ ]
ii. What actions are required for ALARA, such as special water levels for radiation protection?	[ ]		[ ]	[ ]

C. Implementation	**Option 1**	**Option 2**	**Option 3**	**Option 4**
8. Can the option be implemented without special tools or techniques?	[ ]	[ ]	[ ]	[ ]
i. What special foreign material exclusion (FME) tools, techniques, or materials are required?	[ ]		[ ]	[ ]
ii. Is special handling equipment required?	[ ]		[ ]	[ ]
iii. Are there any special storage requirements?	[ ]		[ ]	[ ]
iv. Are there any special shipping requirements for components, tools, etc. needed?	[ ]		[ ]	[ ]
9. Will all tools, equipment or new components needed for the option fit within the existing containment equipment hatch?	[ ]	[ ]	[ ]	[ ]
10. Can the option be implemented without excessive waste being generated?*	[ ]	[ ]	[ ]	[ ]
[ ]				
11. Can the option be implemented without added risk of loose-parts generation?	[ ]	[ ]	[ ]	[ ]
i. If no, how will risk be mitigated?	[ ]		[ ]	[ ]
12. Can and will the option be implemented under a 50.59 process? (MHI to provide their best assessment based on conventional 50.59 process.)	[ ]	[ ]	[ ]	[ ]
[ ]				
i. What are the basis and impacts?	[ ]		[ ]	[ ]

Attachment 1

D. Operational Impact	Option 1	Option 2	Option 3	Option 4
1. Can the option be implemented without requiring special on-line monitoring of the SGs?	[ ]	[ ]	[ ]	[ ]
2. Can option be implemented without changing existing plant parameters, such as SG water level or feedwater and primary coolant temperatures?	[ ]	[ ]	[ ]	[ ]
[ ]				
3. Can the option be implemented without changing operation, surveillance, or other station procedures, programs, or engineering analyses (e.g., linear & non-linear vibration, seismic response, MSLB related reports, etc.)?	[ ]	[ ]	[ ]	[ ]
4. Can option be implemented without need for special training of plant personnel due to repair?	[ ]	[ ]	[ ]	[ ]
5. Will the new hardware be compatible with future chemical cleaning, upper bundle flushing, normal chemical additions, or other maintenance activities?	[ ]	[ ]	[ ]	[ ]
i. How has MHI demonstrated the materials are compatible with the SG primary and/or secondary chemistry and plant requirements?	[ ]		[ ]	[ ]
[ ]				
6. Can the option be implemented without additional future sludge accumulation or long-term tube fouling?	[ ]	[ ]	[ ]	[ ]
7. Can the option be implemented without inducing new thermally induced relative motions of tubes and AVBs and TSPs during plant heatup and cooldown and/or cause other design basis transients as a result of future tube plugging and new hardware?	[ ]	[ ]	[ ]	[ ]